ABSTRACT

Quantum computation is an emerging paradigm that harnesses the principles of quantum mechanics to process information in fundamentally new ways. This thesis explores the application of quantum computing to signal and image processing, focusing on both hybrid quantum-classical methods and purely quantum algorithms.

Quantum computing offers the potential to solve certain computational tasks more efficiently than classical methods, leveraging phenomena such as superposition, entanglement, and quantum parallelism. These features allow the exploration of exponentially large solution spaces simultaneously, which is particularly beneficial for combinatorial optimization, high-dimensional data analysis, and large-scale image processing problems.

Hybrid approaches integrate quantum algorithms with classical techniques to tackle challenging tasks in data analysis and optimization. Specifically, quantum machine learning frameworks were developed for binary and multiclass classification, including ECG signal classification and image classification on the MNIST dataset, demonstrating improved accuracy through quantum feature transformations and classical-to-quantum transfer learning. Variational quantum algorithms, such as the Variational Quantum Eigensolver (VQE) and Quantum Approximate Optimization Algorithm (QAOA), were employed to optimize sen-

sor configurations in sparse beamforming for maximum array gain and signal-to-interference-plus-noise ratio, as well as for sparse Direction-of-Arrival (DoA) estimation using Hamming-weight-constrained QAOA. Additionally, QAOA was applied to superpixel-based image segmentation, achieving superior performance compared to classical spectral clustering.

On the other hand, purely quantum techniques were investigated to leverage the unique advantages of quantum computation. A state matching algorithm was developed to efficiently quantify the similarity between quantum states, reducing qubit requirements compared to conventional approaches. This method was further extended to quantum image matching using the Flexible Representation of Quantum Images (FRQI) framework, enabling pixel-wise similarity evaluation for grayscale images.

Together, these studies demonstrate that quantum computing can address computational challenges that are either intractable or inefficient for classical systems. By combining hybrid and purely quantum approaches, this work illustrates how quantum algorithms can enhance signal processing, optimization, and image analysis, providing promising alternatives and potentially superior performance compared to classical methods. The results emphasize the practical feasibility, efficiency, and unique capabilities of quantum computing for complex real-world problems.